The radiative effect of supercooled liquid and mixed-phase clouds over Greenland by active satellite remote sensing

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INTRODUCTION

Mixed-phase clouds are important players in the global climate system with a strong impact on the energy budget. Yet, this impact remains a key uncertainty in climate models, limiting the reliability of future climate projections. Much is unknown about the physical properties of mixed-phase clouds, including frequency of occurrence, liquid/ice partitioning, and vertical distribution of liquid and ice water contents. Ground-based observations of mixed-phase clouds do not provide extensive spatial information, leaving the large-scale effects of these clouds unknown. Here we show the potential of active satellite remote sensing to observe mixed-phase clouds over Greenland and assess their radiative impact.

METHODOLOGY

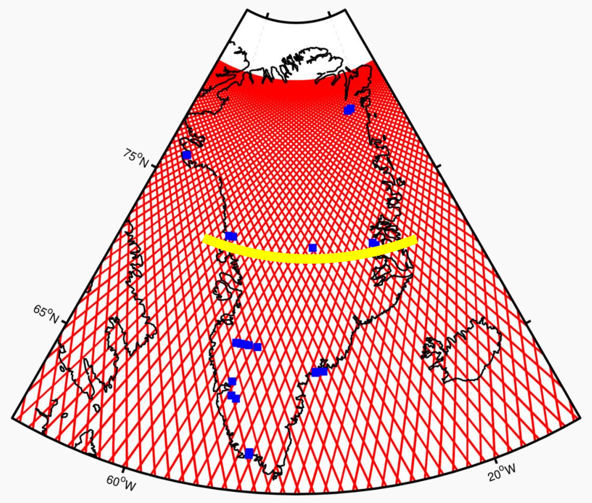


Fig. 1: CloudSat/CALIPSO overpasses over Greenland, AWS locations and West-East transect shown in Fig. 2

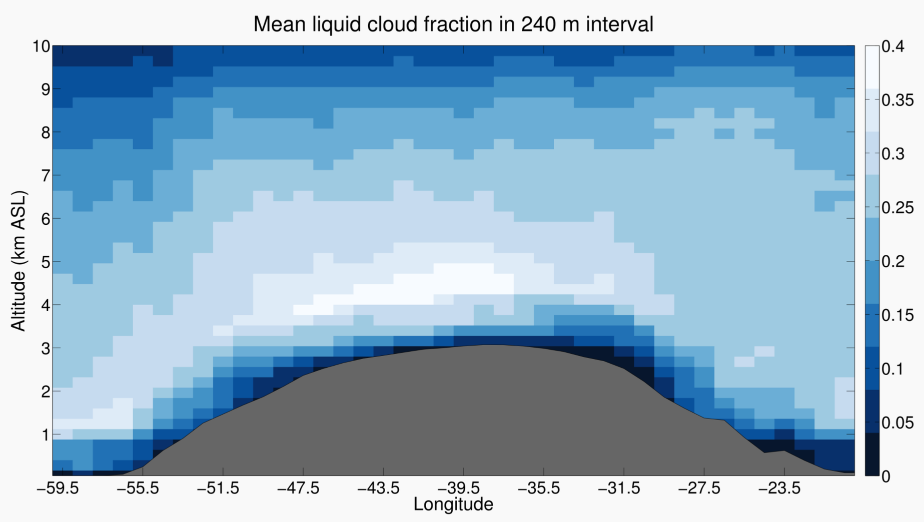


Fig. 2: Active radar (CloudSat) and lidar (CALIPSO) for vertically resolved detection of clouds

2B-FLXHR-LIDAR[1] algorithm retrieves broadband (LW and SW) radiative fluxes based on satellite observations

- CloudSat/CALIPSO/MODIS satellite observations
- Complementary radar and lidar for cloud detection
- Good temporal/spatial resolution (Fig. 1)
- Detection of low-level liquid clouds that previously remained undetected

Cloud radiative impact study

- Flux algorithm is run with and without cloud water contents
- Resulting fluxes allow calculation of cloud radiative forcing
- ~6.3 million observations between 2007-2010
- First Greenland-wide observationnally-based assessment of cloud radiative impacts

2B-FLXHR-LIDAR[1]
algorithm

For every vertical satellite profile

⬇

Look for clouds detected by CloudSat/CALIPSO/MODIS

⬇

Determine LWC/IWC content

⬇ Combine with ECMWF re-analysis

Run radiative transfer model

⬇

Retrieve LW/SW radiative fluxes

RESULTS AND DISCUSSION

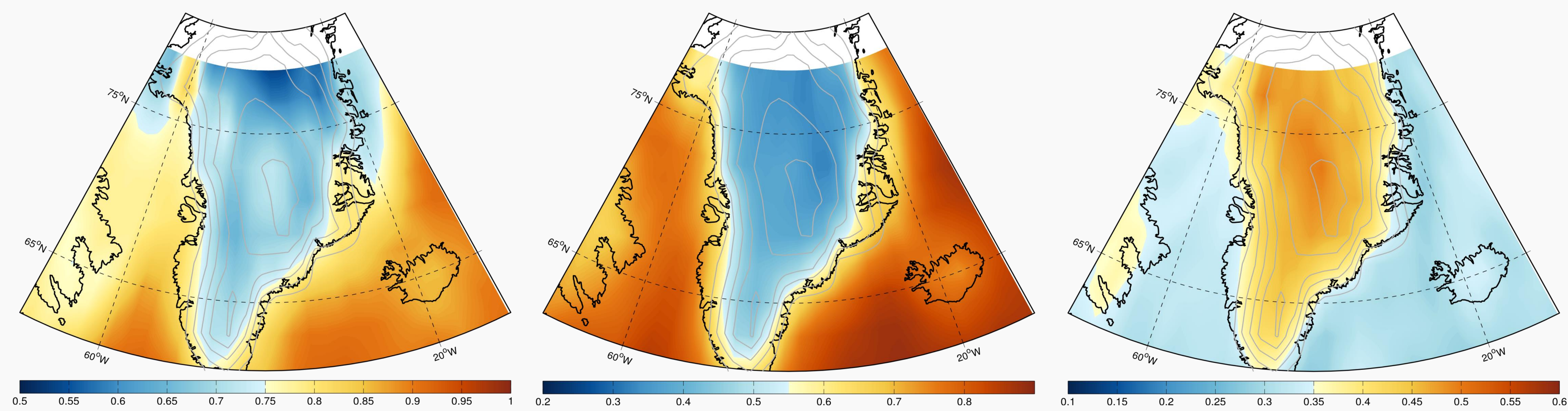


Fig. 3: CloudSat/CALIPSO/MODIS derived maps of (a) total cloudiness, (b) liquid cloud fraction (relative to cloudiness) and (c) liquid cloud fraction within 10 < LWP < 60 g m^{-2} region (relative to liquid cloud fraction)

- CloudSat/CALIPSO/MODIS cloud observations show high cloudiness over most of the ice sheet (Fig. 3a)
- A considerable amount of these clouds contains liquid water (Fig. 3b)
- A high percentage of these liquid clouds falls within the 'thin' region (10 < LWP < 60 g m^{-2}) (Fig. 3c)
- Mean annual cloud forcing of **28.4 (± 4.2) W m^{-2}** (Fig. 4)

Validation of 2B-FLXHR-LIDAR

⇒ Downwelling fluxes at the surface compared to 11 AWS

- Mean bias LW/SW = -2.3/5.8 W m^{-2}
- Mean RMSE LW/SW = 9.8/18.2 W m^{-2}

⇒ Detected clouds compared to ground observations[4]

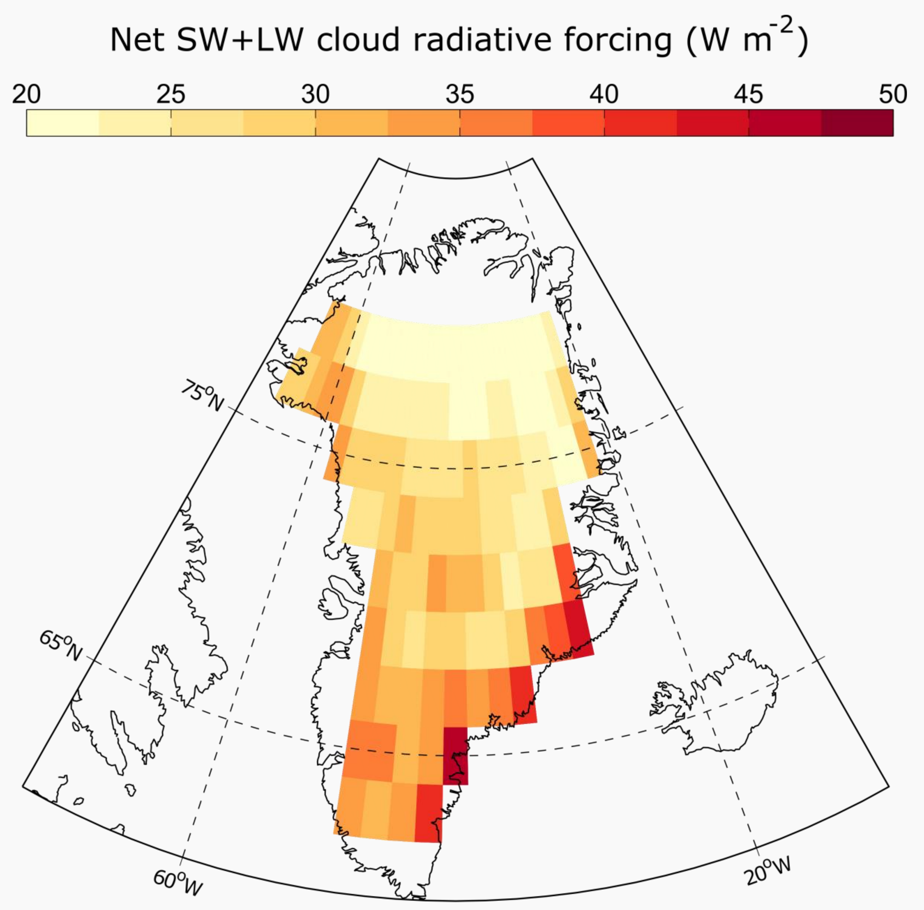
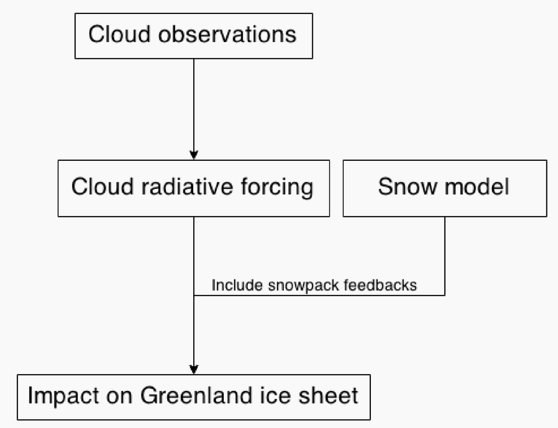


Fig. 4: Yearly annual net cloud radiative forcing shows a strong increase in Greenland ice sheet surface energy input due to clouds.

CONCLUSION AND OUTLOOK

Active satellite remote sensing combining radar and lidar, can effectively be used to observe clouds over the entire Greenland ice sheet. Retrieved microphysical properties are input to a radiative transfer model that indicates that the yearly average net radiative forcing of clouds is strongly positive, increasing the Greenland ice sheet energy input. Further research should focus on how the Greenland ice sheet surface reacts to this increased energy input, to quantify how this affects the surface mass balance. This knowledge is key to understanding the governing mechanisms in the Greenland climate and to improving climate models for future projections.



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[1]2B-FLXHR-LIDAR process description document
[2]Van Tricht et al. *Atmospheric Measurement Techniques*. **2014**, 7, 1153-1167

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